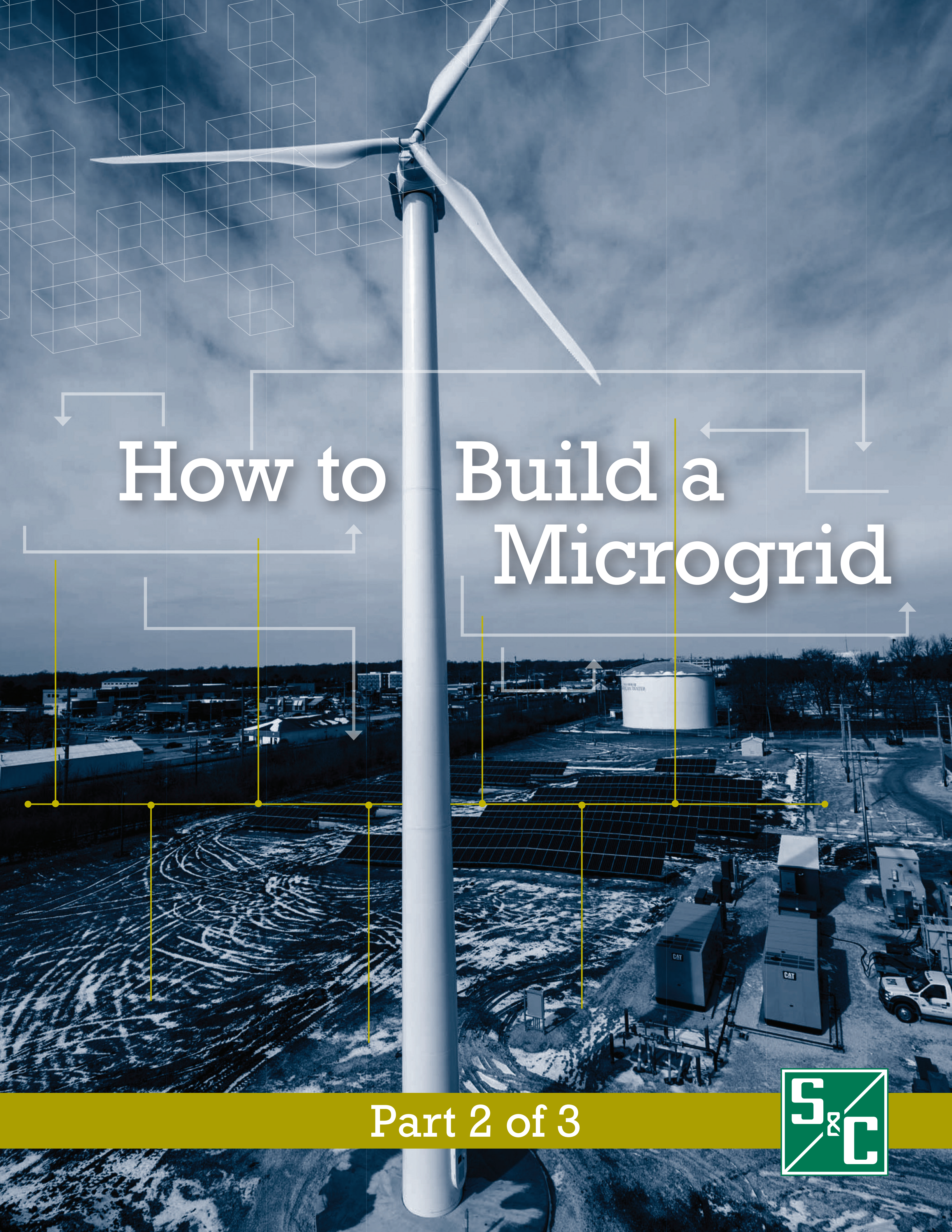


# How to Build a Microgrid

Part 2 of 3

# Your Microgrid PROJECT IS READY TO MOVE FORWARD.

But a microgrid's unique nature can trip up even the most advanced engineers and utility staff.

This handbook is designed to provide industry best practices and help you avoid common mistakes when building a microgrid.

At a different stage in your microgrid project?

Look at these options for more tools and recommendations:


– Is a Microgrid Right for You? (Part 1 of 3)

– The Short- and Long-term Care of your Microgrid (Part 3of 3)

# Contents



# Understanding Your Microgrid Lifecycle

Project Start → Operational Microgrid

## 1 FEASIBILITY ASSESSMENT

The financial, resilience, and sustainability impact will be different for each microgrid. An initial feasibility assessment by a qualified team will uncover the benefits and challenges you can expect from your system.

## 2 30% SYSTEM DESIGN

Often completed during the feasibility assessment, this design lays out the basic technology types, sizes, locations, and methods of interconnecting the microgrid systems.

## 3 COST ESTIMATION & FINANCIAL PLANNING

An accurate project cost estimate drives the feasibility, anticipated benefits, equipment bidding, and budgeting for system operation. This stage also helps you determine who pays for the system. Internal financing allows you to take full advantage of the economic benefits, but third-party financing may be preferable if capital dollars are scarce or if state regulations do not allow utilities to own generation assets.

## 4 SYSTEM ENGINEERING DESIGN & UTILITY INTERCONNECTION

Going from a 30% design to fully fleshed-out blueprints with an interconnection agreement requires a high level of microgrid design expertise and familiarity with distribution equipment.

## 5 PROCUREMENT & CONSTRUCTION

When procuring equipment, consider operating and lifecycle costs over first cost, and don't wait to order large pieces that have long lead times. Then the actual installation requires local know-how and experience working in electrified environments. Pay attention to how and when equipment installation will affect your operations.

## 6 SYSTEM COMMISSIONING

This phase involves factory acceptance testing, site acceptance testing, and system commissioning. Again, consider when commissioning will affect your operations and customers. Training is also part of the commissioning process, which will provide comprehensive teaching on your microgrid's features, functions, and operation.

## 7 OPERATIONS & OPTIMIZATION

Keeping a microgrid operating at optimal performance requires more than regular maintenance. A controller built specifically for microgrids can leverage weather forecasts and pricing signals, as well as system performance data, to continually optimize your microgrid. Having a well-trained operations staff (or contracting with a qualified third party) is critical.

1 2 3

SELECTING THE RIGHT INTEGRATOR *can happen any time in these first three steps and is critical to your project. Some utilities will work with a single team starting at the feasibility assessment point, while others will want to start fleshing out the project first before selecting their implementation team. See the integrator checklist (page 17) for the competencies to evaluate in an integrator.*

# Approaching Microgrid Planning through Four Lenses

## SAFETY

**The nature of microgrid topology generally means power can now flow in multiple directions on your grid.** This means you may need to establish some enhanced safety practices—or at the very least, raise awareness of the risks associated with distributed generation.

## CONTROL

**There are multiple facets to controlling your microgrid and planning for contingencies.** You should know who specifically is in control of your microgrid and whether you can trust your microgrid controller. If the main control box or access to the Internet goes down, what happens to your microgrid? Can you only run in grid-tied mode? Will all generation assets simply run in their previous state until taken offline? Do you need to manually control devices to keep your system stable? Work through scenarios like these until you're confident in your answers.

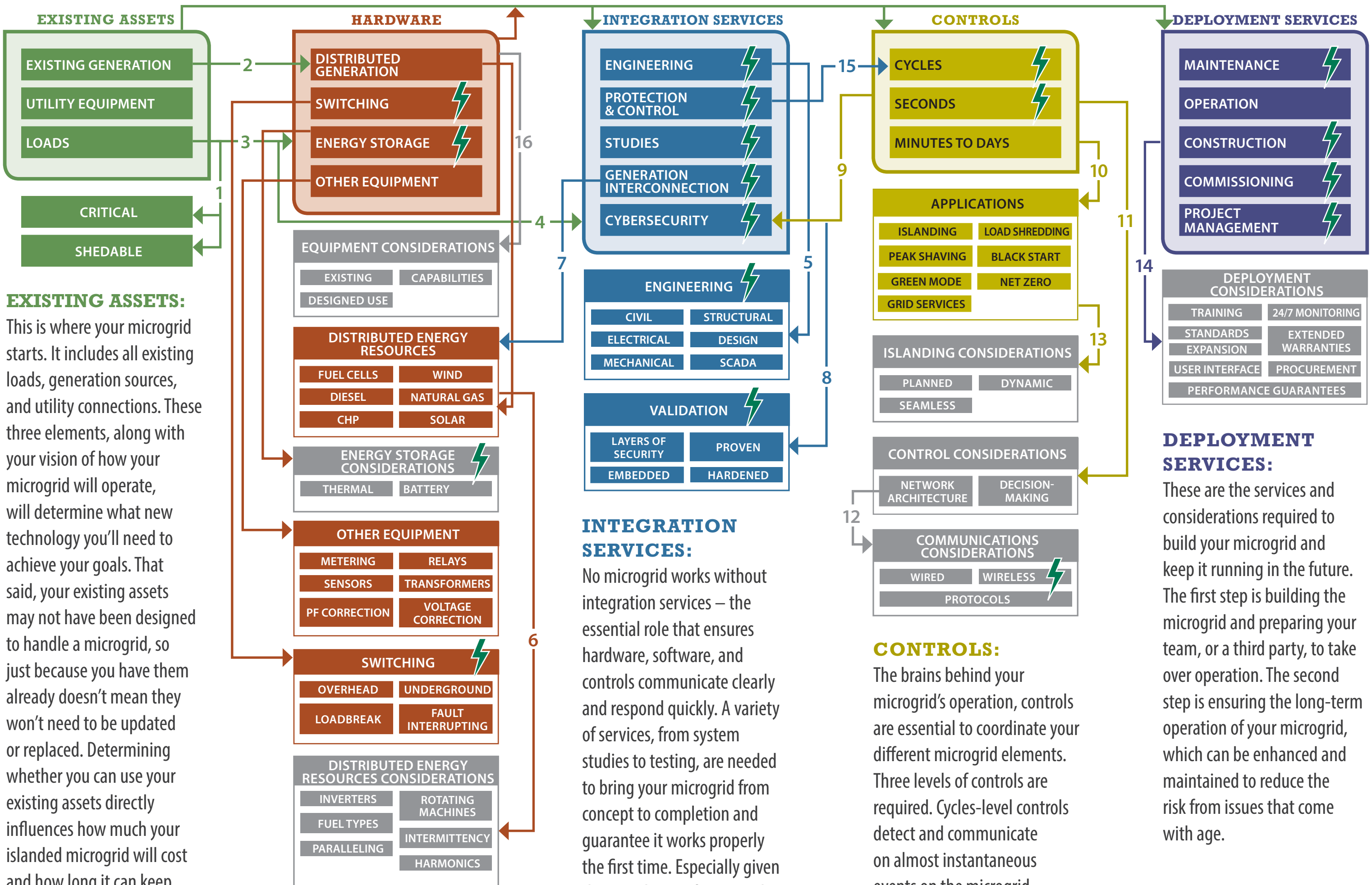
## COST

**Controlling your microgrid's costs starts during design.** If assets are over- or under-sized because of mistakes introduced during engineering, you are either overpaying now (oversized) or underpaying now, but paying much more to fix the mistakes later (undersized).

## ELECTRICAL STABILITY

**Ensuring your microgrid works means you need to verify all use cases in both steady-state scenarios and when load and generation aren't balanced.** This includes fringe cases (e.g., faults on the system, drops in large loads, drops in generation, starting up the grid from an unenergized state), which may only happen occasionally, but the grid must work through them—or at least recover from them. Sizing assets by using a simple spreadsheet to match generation to load isn't sufficient to think through all use cases and scenarios.

# The Components of a Microgrid




## EXISTING ASSETS:

This is where your microgrid starts. It includes all existing loads, generation sources, and utility connections. These three elements, along with your vision of how your microgrid will operate, will determine what new technology you'll need to achieve your goals. That said, your existing assets may not have been designed to handle a microgrid, so just because you have them already doesn't mean they won't need to be updated or replaced. Determining whether you can use your existing assets directly influences how much your islanded microgrid will cost and how long it can keep the lights on when placed in islanding mode.

## HARDWARE:

This includes the various types of technologies and equipment to consider in your microgrid. The choices are vast and depend largely on how you plan to use your microgrid. No matter what you might have been told, microgrid hardware cannot be "plug-and-play;" it will need to be carefully evaluated for a variety of considerations. For example, you must consider the right mix of distributed energy resources and energy storage to ensure your microgrid can achieve your needs.

## INTEGRATION SERVICES:

No microgrid works without integration services – the essential role that ensures hardware, software, and controls communicate clearly and respond quickly. A variety of services, from system studies to testing, are needed to bring your microgrid from concept to completion and guarantee it works properly the first time. Especially given the complexity of microgrids, make sure you aren't paying inexperienced partners to learn on your dime how to build yours.

## CONTROLS:

The brains behind your microgrid's operation, controls are essential to coordinate your different microgrid elements. Three levels of controls are required. Cycles-level controls detect and communicate on almost instantaneous events on the microgrid. Seconds-level controls take this information and make intelligent decisions to constantly balance and adapt the microgrid system. Minute- and hour-level controls react slower after the hard work is done and enable customers to make longer-term changes to their microgrid.

## DEPLOYMENT SERVICES:

These are the services and considerations required to build your microgrid and keep it running in the future. The first step is building the microgrid and preparing your team, or a third party, to take over operation. The second step is ensuring the long-term operation of your microgrid, which can be enhanced and maintained to reduce the risk from issues that come with age.

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**S&C ICONS:**

The S&C icons indicate the different hardware, software, controls, or services S&C offers in-house. This is important because the more systems are designed to work together, the less time you and your integrator will have to spend figuring out how to make them talk, think, and act as one system. This saves you money and greatly reduces risk. **S&C has more microgrid elements under one roof than any other integrator in the world.**

*Please see the next page for descriptions of each numbered arrow > > >*

# MICROGRID ELEMENT CONNECTIONS

< < < *Please view the flow diagram on page 3*

1. Loads are what the microgrid is built for, but not all loads are created equal. Microgrid loads typically fall into two categories.

   a. Critical loads have the highest priority for resilience in the microgrid and have the greatest impact if a power interruption occurs. These include facilities such as command centers, hospitals, community centers, and research facilities.

   b. Shedable loads in the microgrid have a smaller impact for power interruptions. These are typically facilities such as barracks, common areas, housing, or office facilities.

   These two distinctions (a and b) are important because they allow the microgrid to prioritize loads. Even though there are two overarching load categories, the reality is the mix of loads in any microgrid will likely be a spectrum prioritized from the most critical loads to the most shedable loads.

2. Microgrids often start with some form of generation already on-site. These could be existing diesel generators, solar panels, or cogeneration facilities. The existing generation plays a part in determining what additional distributed generation is needed to support the microgrid.

3. The existing utility interconnection also lays the foundation for what additional hardware you may need for your new microgrid. This includes elements ranging from existing relays and meters in your substation and distribution equipment to the number and size of your existing utility connection(s). It's likely your existing utility equipment was not designed to handle the various changes that occur when islanding a microgrid, but an experienced integrator can understand your utility interconnection, reprogram microgrid-capable equipment, or find replacements for equipment that won't be able to handle the intricacies of a microgrid.

4. Your existing utility equipment will also influence the integration services you may require because your utility equipment may need to be integrated into the new microgrid. This ranges from reprogramming relay settings to hardening existing communication systems to a higher level of cybersecurity.

5. Controls are the brains behind the entire microgrid and are incorporated into existing hardware so your distributed generation, switching, and energy storage can think and act quickly.

6. A variety of considerations come into play when determining the right "mix" of distributed generation for your microgrid. These range from the mix of rotating machines to the power and energy capabilities of the generation assets. These are just a small sample of the considerations that are made to choose the right mix of distributed generation for your microgrid.

7. New distributed generation assets can't simply be plugged into the surrounding system. Any new distributed generation assets will require interconnection services to make them a part of your microgrid.

8. Any system that uses communication to operate is vulnerable to cyber threats, and your microgrid is no different. That is why it is essential that the cybersecurity of your microgrid is validated, not by the vendor, but by a third party. Cybersecurity validation involves pressure-testing the layers of security in your system, checking the embedded security within your controls (see point 9), proving your security can withstand attack, and hardening your system toward known threats. You don't want your microgrid to turn the lights on only to have someone other than yourself turn them off.

9. As soon as you have a system of controls talking and communicating to each other, they are vulnerable to cybersecurity threats. Just as a single infected computer can spread a virus to an enterprise network, so can an infected control affect an entire microgrid—hence the indispensability of validated cybersecurity to your project (see point 8).

10. The controls within your microgrid are the brains behind your operation. They are what allow microgrids to achieve all the applications that make them a critical part of grid resiliency. This list isn't comprehensive, but it includes the most common applications for microgrids achieved through the orchestrated coordination of controls.

11. Your controls may be the brains, but they need to be able to talk, and you need to tell them what you want them to do. To decide what kind of controls you will need, consider your current and/or desired network architecture and how you will prioritize decision-making. These are complex decisions but are essential to ensure your microgrid achieves all of your goals.

12. Network architecture involves how your microgrid will talk, which depends on any communications you may already have in place and the applications you would like to use in your microgrid. These are typically split into whether you want wired (fiber, copper) or wireless (radio, cellular) communications. You will also need to decide what language, or protocols, all of your controls and hardware are using. Where there may be gaps in the protocols among different equipment, you'll need a translator.

13. Islanding always is a microgrid application; it's part of what defines a microgrid. That said, there are different forms of islanding, and you'll have to consider which types you want your microgrid to support. Planned islanding is the ability for you to decide when you form your microgrid. Unplanned islanding is when your microgrid reacts automatically when it detects a problem with the grid. Seamless islanding refers to the ability for a microgrid to form a planned or unplanned island without any interruption to loads. Dynamic islanding is how your system adapts to the unplanned, such as a loss of generation or a fault, once the microgrid has formed.

14. Deployment services are the physical creation of your microgrid, but there are many additional factors to consider regarding operations. This is not a comprehensive list, but an experienced integrator should review elements such as these with you to be sure you are ready to use, take care of, and grow your microgrid in the future

15. Protection and control engineering are needed for your whole microgrid as well as cycle-level controls. These controls act almost instantly and must be carefully programmed by protection-and-control experts to differentiate between grid-connected and islanding mode.

16. Before deciding what new assets you'll need to build for your microgrid, you'll first need to evaluate what you already have. A good integrator should help you evaluate the capabilities and designed use of your existing equipment to determine how much support they can provide your microgrid, which will influence what new equipment you may need.

# Microgrid Myths

**MYTH: If I understand utility systems or the components of a microgrid (e.g., solar PV, energy storage, or generators), I understand microgrids.**

Microgrids are completely different from the main grid or working with individual distributed generation sources. Getting all the components within microgrids to work together safely and reliably is its own expertise. For example, most types of distributed energy resources weren't designed to be combined with other types. Also, electrical systems are extremely safe because on-board protection schemes trip them off when anomalies are detected. But in a microgrid, protection schemes must be adaptive and account for system parameters differing between grid-connected and island modes. Experience matters in orchestrating multiple devices to work well together safely and reliably.

**MYTH: All microgrids are the same.**

If you've seen one microgrid, you've only seen one microgrid. Each microgrid must meet the unique requirements for the generation sources, load profiles, and use cases at each site. In most cases, microgrids blend existing and new infrastructure at each installation site, making exact duplications rare and "plug-and-play" options impractical.

**MYTH: Microgrids are so complicated, they make your problems worse.**

The right microgrid partner can make complexity easy by building in flexibility and versatility to switch among multiple use cases in real time. If you have the right design, components, and control system, software will automatically manage your microgrid.

**MYTH: Seamless transfer is necessary.**

Switching your microgrid from grid-connected to islanded mode and back without anyone noticing is an intuitive goal (and entirely possible), but not always necessary. It's important to define your needs. For example, in many cases, one minute of power loss may be acceptable, but five minutes may not be. Seamless transfer can be a costly engineering challenge, so seek this option for only when and where you need it.

**MYTH: The more a microgrid can do, the better it will be.**

Microgrids can achieve many use cases, but not all of them are useful at every location. It's important for maximum reliability and minimum cost to tailor microgrid design to provide exactly what you need—and nothing you don't.

**MYTH: Energy storage is required to run a microgrid.**

Many of your microgrid's use cases can be met by using only distributed energy resources. Although energy storage provides a myriad of benefits and flexibility to a microgrid, it is not always required. Determining whether energy storage is necessary depends on your existing generation mix and how long your microgrid is expected to provide its benefits.

# Self-Assessment: Are You Ready for a Microgrid?

**Even if you have defined some of your microgrid needs, it can be easy to overlook the details. Missing these details can result in increased costs and project delays. Take this self-assessment to be sure you've covered the basics. If you place checkmarks in the "Work on It" column, you have questions you need to answer before moving forward.**

| WORK ON IT | MICROGRID-READY SELF-ASSESSMENT | COMPLETED |
|---|---|---|
| | **STEP 1: DETERMINE WHAT YOU WANT THE MICROGRID TO DO.** | |
| | You've mapped its function back to the problems you want to solve. | |
| | You know which of your electrical loads are the most critical. | |
| | You know how fast the microgrid needs to come online when grid power fails. | |
| | You know how long your microgrid must last in islanded mode. | |
| | **STEP 2: DETERMINE POWER SUPPLY.** | |
| | You know what types of generation you want to include in your microgrid. | |
| | You know whether you can own your generation assets or want to use third-party ownership. | |
| | You know how much power you need from your microgrid. | |
| | You know how long you need independent power generation. | |
| | You've performed preliminary engineering studies to confirm the necessary size of generation assets. | |
| | **STEP 3: BRIDGE THE GAP BETWEEN WHAT YOU HAVE AND WHAT YOU NEED.** | |
| | You know the infrastructure and equipment that's currently in place. | |
| | You know how existing assets (and future planned assets) will line up with existing loads. | |
| | You know how and when power will flow within your microgrid. | |
| | **STEP 4: LOCATE THE BEST PLACE TO BUILD.** | |
| | You know how the topology and site features match up with the generation you'd like to use *(e.g., enough sun penetration for solar PV)*. | |
| | You understand any potential community concerns around the microgrid (visibility, emissions, etc.). | |
| | You understand the local community or how nearby feeders might be affected by your microgrid. | |
| | You know whether the microgrid might overload a line that may already have too much distributed generation. | |
| | **STEP 5: DETERMINE THE MICROGRID'S BOUNDARIES.** | |
| | You know how you will you connect buildings to the energy sources. | |
| | You know how many switching procedures you will have to start/stop the power flow and where they will be. | |
| | You know where there is existing communications infrastructure, and your microgrid will leverage it. | |
| | **STEP 6: LINE UP FINANCING, STAKEHOLDERS, AND YOUR TEAM.** | |
| | You know how you'll pay for your microgrid (e.g., using O&M costs, capital, grants). | |
| | You've received regulatory approval. | |
| | You have buy-in from both your executives and your customers. | |
| | You know who internally is available to work on this project and where you might need support from a third party. | |
| | You know whether you want to maintain your microgrid or outsource the task. | |

**PRO TIP:**
Often it's easiest to analyze where critical infrastructure and/or generation assets currently exist and build around that.

**PRO TIP:**
The fewer switching procedures, the better. Not only will this save you money by making the engineering less complex, but this means there's less to manage and less risk you've opened yourself up to.

**PRO TIP:**
Putting in new communications infrastructure is often expensive; it might be cost-effective to have existing infrastructure dictate boundaries.

**PRO TIP:** Even when you're in the initial stages of planning your microgrid, always keep the long term in mind. Especially if you might expand your microgrid in the future, it's often less expensive to plan now for an extra way in your switchgear or another 50 feet in fiber-optic cables than to add them later. Also, when it comes to maintenance and software updates, consider whether you want to maintain the microgrid in-house or budget for a partner offering long-term support services. An external partner could be the provider of your microgrid or a separate third party.

# Compliances You Need to Know About

**PRO TIP:**
Acquiring interconnection and asset permissions can take 12 to 24 months. Don't wait to begin the process.

## 1. 1547-2018 - IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems

The grid wasn't built to handle power generation or energy storage at the distribution level. In recent years, distributed generation has fundamentally changed the way the grid operates, and the industry has learned some lessons along the way. To avoid dangerous accidents, IEEE Std 1547 outlines the requirements and technical specifications for interconnecting distributed resources safely with the grid. This includes design, testing, equipment, production, installation, and more.
*https://standards.ieee.org/findstds/standard/1547-2018.html*

## 2. P2030.7 - IEEE Draft Standard for the Specification of Microgrid Controllers

The microgrid controller, or the Microgrid Energy Management System (MEMS), is the brain of the microgrid and gives orders to other equipment within its boundaries. However, microgrids often comprise equipment from different suppliers, so it's important to be sure all components can operate cohesively and talk to the controller. IEEE Std P2030.7 ensures interoperability of the microgrid by defining which parts of the microgrid controller must be standardized and which can remain proprietary.
*https://standards.ieee.org/develop/project/2030.7.html*

## 3. Clean Air Act from the U.S. Congress & the U.S. Environmental Protection Agency

For microgrids in the United States, the Clean Air Act establishes requirements for air quality. These requirements affect how fossil-fuel generators can be used in microgrids. These standards, based on the latest research and science, set limitations on hazardous and toxic pollutants. Enforcing these requirements falls to state, local, and tribal authorities to monitor air quality within and across borders.
*https://www.epa.gov/clean-air-act-overview*

## 4. IEC 61727 – International Electrotechnical Commission's Photovoltaic (PV) System Requirements

This international standard outlines requirements for photovoltaic systems interconnecting with low-voltage utility distribution systems.
*https://webstore.ice.ch/publications15736*

# What to Look for in Equipment

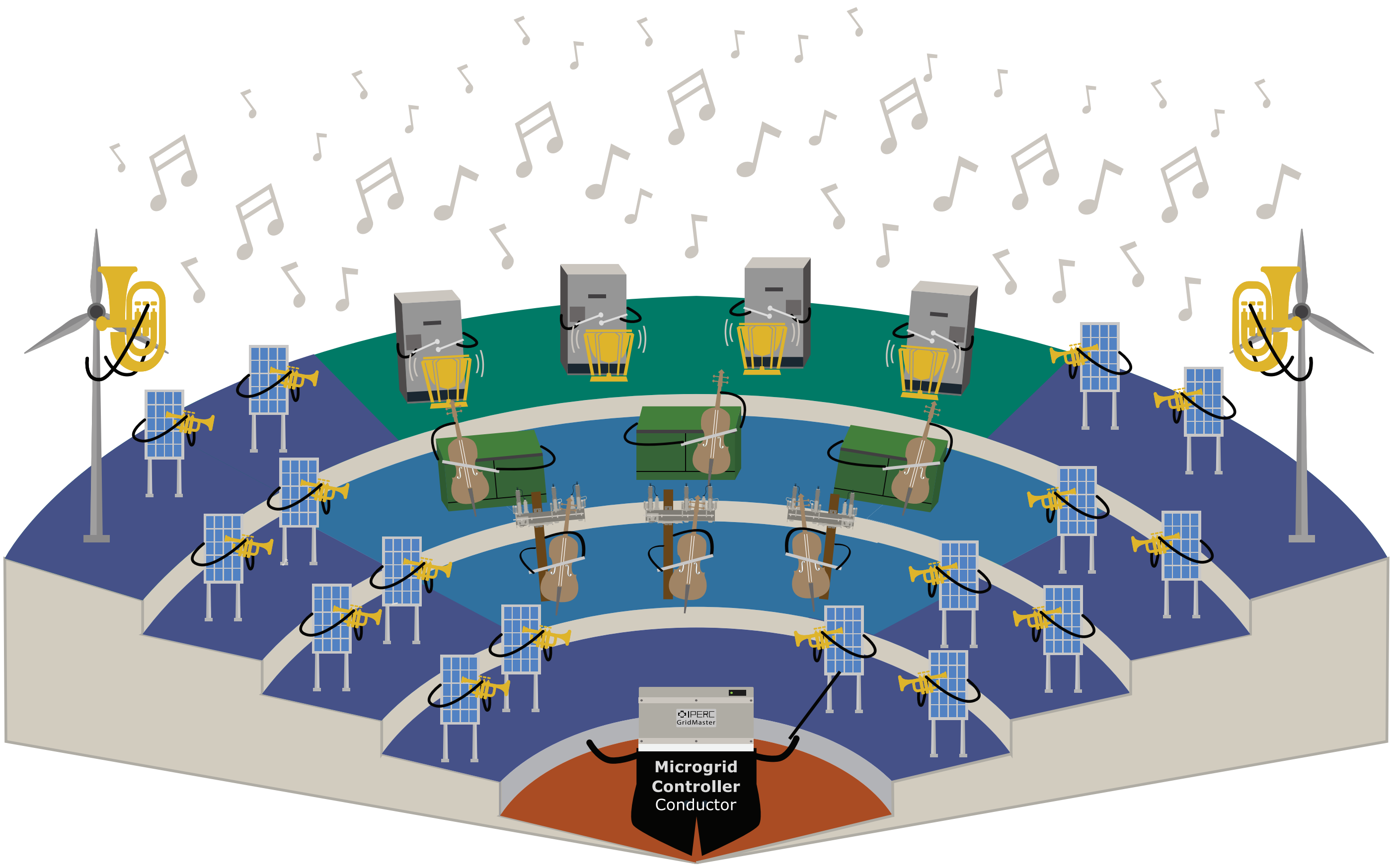
Not all equipment is "microgrid-friendly." As you're considering equipment, go through this evaluation with each piece of existing and new equipment to be sure it's well-suited for a microgrid environment. All your checkmarks should land in the "Yes" column. If not, consider alternatives.

| Characteristics of "microgrid-friendly" equipment | Yes | No |
|---|---|---|
| **REMOTE CONTROLLED**<br>Remote-control capability will depend on the functions each piece of equipment serves. For example, you can find generators that turn off remotely but can't be turned on remotely. For a microgrid, you'll need both for transitioning in and out of islanding mode. | | |
| Can the equipment be turned on remotely? | | |
| Can the equipment be turned off remotely? | | |
| Can other operating parameters be adjusted remotely? | | |
| **SOPHISTICATED AND FLUENT COMMUNICATIONS**<br>Although it seems obvious, equipment must talk to each other—but this can be challenging if equipment is purchased from multiple suppliers. Your equipment's fluency is important for functionality as well as for safety and security. Also, the more variables your equipment can report out on, the more valuable it becomes because you can better understand your microgrid and "tune" it for optimized performance. | | |
| Can the equipment accept commands from the control system? | | |
| Can the equipment perform its intended function as a result of communicating with the control system? | | |
| Can you view performance logs and monitor your equipment remotely? | | |
| Can the equipment send information about its status to the control system? | | |
| Can the equipment send real-time information to the control system beyond its status that monitors performance details (e.g., fuel level or temperature of fossil fuel generator)? | | |
| **FLEXIBLE AND ADJUSTABLE PERFORMANCE PARAMETERS**<br>Having flexible control allows you to efficiently control both generation and loads within the microgrid. For example, PV plants generally push out 100% of the power they generate. If the power output exceeds what the microgrid can use, the PV would normally be switched off altogether. But there are times when you might only want 60% of available output, and a system configured with dynamic curtailment and a microgrid controller can allow this flexibility. | | |
| Have you determined which pieces of equipment need adjustable parameters? | | |
| Of the equipment that need adjustable parameters, will those parameters be flexible enough to meet the microgrid's objectives? | | |
| **FLEXIBLE PROTECTION SCHEMES**<br>Devices' protection schemes are different when the main grid is no longer available. Typically, the tolerances for equipment on the grid are so tight because they're built to trip off the device quickly when there's a problem, but equipment in a microgrid needs a greater degree of tolerance to allow the microgrid to adjust and flex as it responds to changes in its micro-environment. | | |
| Will the device's protection settings inhibit it from operating in a microgrid? | | |
| Have you defined what your new protection and control schemes will be? | | |
| Have you planned for new arc-flash studies with your equipment? | | |
| **APPROPRIATE END-OF-LIFE RATING**<br>Equipment deteriorates over time, so you must be sure your equipment can still handle the microgrid's loads at any point in time. If you need a battery to last two hours for 10 years, you may need to buy a battery with a beginning-of-life rating of three hours. | | |
| Will your equipment last for the duration of your microgrid's life (typically 20 years or more)? | | |
| If a piece of equipment isn't designed to last for the duration of microgrid, have you budgeted and planned for when those replacements need to occur? | | |

# Why is the Microgrid Controller so Important?

## The controller for components in a microgrid is like a conductor for instruments in an orchestra.

The conductor signals to each instrument section when to play and how loudly. Only with the conductor can all the instruments sound harmonious and create beautiful music together.



# There's More to Security than a Firewall

**Keeping attackers out of your system is one tactic of cybersecurity, but it's not the sole objective.**

The overall goal is to minimize the damage attackers can do to your system. If attackers get inside your network, it's critical that your system has multiple lines of defense to keep them from doing damage. Here are a few common protection mechanisms:

### Firewall

Network perimeter hardware and/or software configured to prevent unauthorized access

### Encryption

Transforming data into a cipher so that it's unreadable to those without unique decryption keys

### Hardware Hardening

Identifying and fixing physical vulnerabilities on a system

*(e.g., locking enclosures or disabling USB ports)*

### Software Hardening

Identifying and fixing software/code vulnerabilities on a system

*(e.g., removing code extraneous to microgrid operation)*

### Authentication

Ensures the identity or legitimacy of a person, device, or data stream connecting to the system

### Whitelisting

Automatically allowing ONLY the devices, applications, or communications that are "on the list"

### Intrusion Detection

Monitoring and analyzing a system's or network's traffic to discover malicious activity

## Why is a firewall not good enough?

Firewalls are a necessary network-perimeter protection, but it's not uncommon for hackers to breach them. If this occurs and there are no other lines of defense, all network systems and data are immediately vulnerable to catastrophe. Don't dismiss the thought of an insider threat, such as a rogue employee, who is already behind your firewall and could wreak havoc on your system.

# 21 QUESTIONS TO ASK YOUR MICROGRID CONTROLS PROVIDER

Because your controls are so critical to your microgrid operating safely and efficiently, it's important to screen potential controls providers thoroughly. Ask each provider these 20 questions and circle the answer that most closely applies to them. Choose a provider that has most or all of the answers in the "Passes the Test" column.

| | Questions to Ask | ANSWER: Not Good Enough | ANSWER: Passes the Test |
|---|---|---|---|
| 1 | **Can we see your controller?** | Can only show us a rendering/drawing of the controls and will only build it if we buy it | Can show us the controls in person, as well as offer a tour of a site or show pictures of its use in operational microgrids |
| 2 | **What is the performance history of your controls in the field?** | Can't reference specific completed projects and active systems | Can provide a list of projects, their locations, and when they were commissioned, as well as provide references |
| 3 | **What different kinds of equipment have been connected with these controls?** | Only a few | They've worked with switchgear, renewables, electric vehicles, energy storage, and fossil-fuel generators (including diesel and natural gas)—both new and legacy equipment |
| 4 | **If you have legacy equipment, can the controls integrate them into the new microgrid system?** | No, everything has to be new, so we wouldn't be able to use what we already have | Yes, so we won't have to worry about integrating our equipment |
| 5 | **Does the base controller product need add-on hardware to communicate with the controlled equipment?** | Requires purchasing and configuring additional hardware to operate the controller | We'd be purchasing a complete controller package |
| 6 | **How many and with which standard and proprietary industrial communications protocols are the control system currently compatible?** | Only one or two | The controller is multilingual (e.g., ModBus, CAN bus, DNP3, proprietary digital generator controllers, BACNet) |
| 7 | **What communications media options (e.g., fiber optics, serial, Ethernet, wireless) are currently available for the controller to talk to the microgrid components?** | The type(s) we don't have or want | The type(s) we do have or want |
| 8 | **How do human operators monitor and issue commands to the control system, locally and remotely?** | Can only be accessed on custom software on a single computer that lives onsite at the microgrid. If hardware or software fails, the system will shut down, we'll be blind to what's happening, and we'll be stuck offline at the microgrid until a vendor fixes the issues. | Through an easy-to-use interface that can be run on any browser and on any device we've granted access to, whether devices are onsite or remote. This allows us to monitor and troubleshoot from anywhere, even if one of the operating devices fails. |
| 9 | **Can the sophistication of the control algorithms handle complex circumstances?** | Uses sequential if-then logic common to Programmable Logic Controller (PLC) systems, which can't handle complex systems where multiple factors play into decision-making and outcomes | Can efficiently take multiple dynamic input and output factors into account, which is important for complex microgrid decision-making |
| 10 | **Was the control system originally designed specifically for microgrids?** | No, it shoehorns control software and hardware developed for other applications (e.g., industrial machinery controls) into a microgrid, which may result in performance gaps and system weaknesses | Was developed specifically to be a secure control system for energy microgrids |

Because microgrids often use equipment from different manufacturers, controls tend to encounter many protocols, hence the reason why a controller that's only fluent in one or two protocols might be limiting.

You might be fine with a controller that only has one or two options available, so long as it's well-versed in what you need. However, be sure you're thinking long term. If you ever want to expand your microgrid or add a new piece of equipment, will your controller be able to communicate with more than what you originally had planned?

*Continued on next page > > >*

# 21 QUESTIONS TO ASK YOUR MICROGRID CONTROLS PROVIDER

*Continued from previous page > > >*

| | Questions to Ask | ANSWER: Not Good Enough | ANSWER: Passes the Test |
|---|---|---|---|
| 11 | **Is the software scalable, allowing straightforward future expansion of both loads and generation?** | Requires rebuilding large portions of the underlying control algorithms, a time-consuming, potentially costly and risky process | Expansions can be handled as modifications to system parameters rather than rewriting algorithms, making modifications easy and fast |
| 12 | **What actions are required to update or reconfigure the control system (e.g., fix software bugs or incorporate a new component to the microgrid)?** | Must take the system offline for days or weeks or execute another invasive process | Can overwrite software remotely or in the field without shutting down the system |
| 13 | **What is the age of the oldest code currently in use?** | More than 5 years | Less than 5 years, incorporating current cybersecurity standards |
| 14 | **If something were to go wrong with the control system, what are the fail-safe sequences to ensure the microgrid components remain operational?** | Whole microgrid goes down with it, maybe turning everything off or—worse—damaging connected equipment | Triggers a "first, do no harm" principle where the controller disengages and puts the connected equipment back in the operating mode before the control system was installed |
| 15 | **What cybersecurity and information-assurance protections does the control system provide?** | A firewall is the first and only line of defense | Has multiple, interlacing webs of security, such as a firewall, encryption, hardware hardening, software hardening, intrusion detection, whitelisting, and authentication |
| 16 | **Does the control system have a history of withstanding spyware (i.e., has it ever been hacked)?** | No, it's either failed against hackers or can't say it's been put to the test | Yes, and can cite what it's fended off and when |
| 17 | **Has the control system undergone a thorough independent evaluation of cybersecurity?** | No, the only assurances regarding the system's level of cybersecurity is the provider's own claims | Yes, and the control system received high marks for resiliency against attacks using the latest penetration techniques |
| 18 | **In which countries has the control software been written?** | We're concerned that where the software was written may expose my microgrid to risk | We feel comfortable with where the software was written |
| 19 | **Does the control system provider have any foreign ownership or management interests?** | We're concerned these relationships may expose my microgrid to risk | We feel comfortable with the company's ownership, relationships, and business interests |
| 20 | **What are the terms of the system's site license and/or tech support?** | Provider won't support us after our microgrid is commissioned, or the hourly rates and resolution time required to fix even minor problems are exorbitant | Support is long-term and comes with contractually based response times—and there's a 24/7 monitoring option if we want it |
| 21 | **What's included in the system's cost?** | Up-front cost only, which does not include modifications or support down the road | Lifetime costs, which factors in training, maintenance, and security updates |

Code built years ago, especially in the 1980s and 90s, typically has no cybersecurity protection because the threat wasn't as severe then.

The strongest accreditation is the Department of Defense's Authorization to Operate (ATO).

# What to Do if You're Over Budget

*NOTE: The bare bones of a microgrid must include the load, generation, suitable infrastructure, controls, and a communications network.*

## Did you draw up your dream microgrid—only to realize your budget can't cover it?

**You can likely find a compromise between what you want to create and the cost by reducing the project scope in one of these four ways:**

**SIZE**

What's the minimum amount of power your microgrid needs?

**BOUNDARIES**

Is there infrastructure in your microgrid that isn't critical and doesn't need to be within the microgrid's boundaries?

**USE CASES**

How many of your use cases are must-haves versus nice-to-haves?

**TIMELINE**

Can you start off by making a smaller version of your microgrid and then scale later?

# Integrator Evaluation Chart

**Because microgrids combine many types of equipment, it's important to choose an integrator that is skilled in every competency needed. As you're reading through proposals, add each integrator to the chart. Rank them on a scale of 0 (no capability) to 3 (full capability) in each competency. The one with the highest score reveals the most capable.**

| Competency | Integrator 1 | Integrator 2 | Integrator 3 |
|---|---|---|---|
| | | | |
| **POWER SYSTEM DESIGN**<br>Because your microgrid is a grid microcosm, your integrator should have in-depth familiarity designing systems. Your integrator should also be well-versed in distributed energy resources; they will act differently around each other. Not understanding this can make for costly changes along the way. | | | |
| **RELAYS**<br>Protective-relay programming isn't the same within a microgrid. Your integrator should know how to program relays when you are operating in island mode with inverter-based generation sources. | | | |
| **CONSTRUCTION**<br>Having a construction manager to oversee and build your microgrid ensures its design will be brought to life smoothly, efficiently, and accurately. | | | |
| **CONTROLS**<br>Given that the controls are the brain of the microgrid, it's a major advantage if your integrator offers the best-in-class control system that has already been installed. Controls should be sophisticated to handle complex decision-making and contingency-handling within a microgrid, have multiple cybersecurity defenses, and show proven functionality with real projects. | | | |
| **DISTRIBUTION EQUIPMENT INTEGRATOR**<br>As a utility, the distribution will be a critical component of the microgrid. An integrator needs to know this equipment inside and out so there won't be any surprises or time lost in learning functionality. This will reduce integration time and lower overall deployment cost. | | | |
| **PAST PROJECT EXPERIENCE**<br>You don't want inexperienced integrators learning on your dime or jeopardizing your project. Investigate whether your integrator can cite existing, successful microgrids they've engineered and built. | | | |
| **LONG-TERM SUPPORT**<br>After-commissioning support is a must. Although the microgrid industry is growing, it's not as mature as other markets. Because microgrids are complex, there will need to be some tweaks made later. | | | |
| **TRUST AND LIKEABILITY**<br>You'll be working with your integrator closely and for a long time. Do you have an impression that you'll like working with them? Do you trust their expertise to find solutions to unforeseen challenges? | | | |
| **Total Score:** | | | |





# Relationship Advice: Working with Your Integrator

1. **Choose an experienced partner.** ***Your project isn't a science experiment.*** You don't want a partner testing out their theories for how microgrids work on your system. You want a partner who has proven success in microgrids.

2. **Seek a small, dedicated team.** Investigate how many companies are on your integrator's team to be sure you have resources dedicated to your project. If you get the sense there are many people on your project who are also working on other projects simultaneously, this could result in lack of focus and taking shortcuts on your project.

3. **Pick team captains.** Within both your own team and your integrator's, it's helpful to have a point person so you know exactly how information will be passed from one team to another and so each team has a manager in charge of overseeing the project.

4. **Involve your microgrid integrator early on.** Because microgrids are complex, small decisions can have a big impact. Rely on your integrator's expertise even in the initial stages of system analysis and design so your integrator can help you steer in the right direction and avoid expensive course corrections later. Early involvement also ensures your integrator can align with your vision from the start and quickly make informed recommendations and decisions.

5. **When applicable, choose equipment familiar to your microgrid integrator.** Because equipment acts atypically around other devices in a microgrid environment, it will be easier for your integrator to make adjustments if they're already familiar with applicable equipment—and the equipment's common use cases. Include your integrator in choosing equipment to avoid unnecessary and unwanted surprises. It will help your integrator better predict trouble spots and how all pieces of the microgrid will act together.

# Notes

## At a Different Phase in Your Microgrid Project?

Look at these options for more best practices:

Is a Microgrid Right for You? (Part 1 of 3)

The Short- and Long-term Care of your Microgrid (Part 3 of 3)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